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LEVEL II

THE IMPACT OF FEMALE ANTHROPOMETRY ON THE U. S. ARMY

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During the past 30 years, several major anthropometric surveys have been carried out in the U. S. Army. Large numbers of both men and women were measured in 1946, at the end of World War II (1,2,3). Army men were measured again in 1966 (4), while Army aviation personnel were measured in 1959 (5), and again in 1970 (6). The most recent survey of Army women was made in 1977 (7,8,9). A small sample of men also was measured in order to obtain directly comparable data (10). The importance of the latter anthropometric survey of U. S. Army women is the subject of this paper.

An essential element in the effective development of Army clothing, equipment and other materiel is the availability of information on the body sizes, proportions, and distributions of personnel in the Army population. Such information is obtained from anthropometric data. Anthropometry is the measurement of the human body, and the resulting measurements, collected during an anthropometric survey, represent the source of the body size information which is required.

A new anthropometric survey of U. S. Army women was planned and carried out in 1977 in response to the need for current and comprehensive body size data for the women who make up an increasingly large part of the United States Army. The main purpose of the survey was to obtain and develop statistical data on body size and proportions. In addition to conventional anthropometric measurements, measurements also were taken on workspace dimensions and on the static muscle strength of Army women.

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During the survey, data for 69 basic body dimensions were obtained on a sample of 1331 women, covering a wide range of age, rank, and military assignment. Additional data were collected on series of between 200 and 300 women for 28 other body measurements, 31 head and face measurements, 14 workspace measurements, and 9 static strength measurements. Many of the measurements made had not been previously reported for any large-scale survey of women, military or civilian. Other measurements were selected to supplement data already available to provide up-to-date information for use in the design of clothing, protective equipment, workspace and industrial equipment which women in the Army wear, use, operate or within which they work.

Standard anthropometers, calipers, and steel tapes were used for the measurements. All measurements were made in millimeters, except for weight which was recorded in pounds and tenths. The anthropometric data initially were recorded on data sheets and subsequently transferred to punch cards. The punched cards then were read into a computer where the data were transferred to magnetic tapes. After an editing process with the use of two separate computer programs for the identification and elimination of errors, the data were processed in order to generate statistical values such as means, standard deviations, ranges, and percentiles.

The results of the 1977 anthropometric survey of U. S. Army women have been published in a series of four technical reports (7,8,9,10). A fifth report, containing further analysis of the data, is in preparation. Representative anthropometric data for both Army men and women also are now published in official Department of Defense documents such as the Military Standard: Human Engineering Design Criteria for Military Systems, Equipment and Facilities (MIL-STD-1472B) (11) and the Military Standardization Handbook: Human Factors Engineering Design for Army Materiel (MIL-HDEK-759) (12).

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Since 30 years had elapsed between the anthropometric surveys of Army women in 1946 and 1977, the first question concerning the results of these surveys inevitably concerns the amount of change in body size. A comparison of the data from the two surveys indicates that there has been relatively little change in the body size of Army women.

Anthropometric data for selected body measurements of Army women from 1946 and 1977 are given in Table 1. Shown here are the number of women measured (N), the mean value, the standard deviation (S.D.), and the range (represented by the minimum, the maximum, and the difference between them). Also shown are stature ratios, obtained by dividing the mean values of the various dimensions by mean stature.

The 1977 sample of Army women was about four years younger on the average than the 1946 women. On the average, Army women in 1977 were three-quarters of a pound heavier and one-third of an inch taller than in 1946; sitting height was one-half inch higher in 1977. In body girth dimensions, the 1977 women were one-quarter of an inch smaller in bust circumference, one and one-half inches larger in waist circumference, and two-tenths of an inch larger in hip circumference than the 1946 women.

Percentile values for selected body measurements of Army women from 1946 and 1977 are shown in Table 2. At the 50th percentile (median) level, dimensions for the 1977 women are greater than those for the 1946 women, except for bust circumference. However, at the 95th percentile level, values for weight, bust and hip circumferences are lower for 1977 women, but higher for stature, sitting height, and waist circumference.

Body Measurements of Men and Women

In view of the increasing numbers, as well as the emphasis and importance of women in the Army, comparisons of anthropometric data for Army men and women are of even more interest and concern than whether women have increased in body size. In the applications of anthropometric data in research and development programs, two areas are of primary consideration. These are in the design and sizing of clothing and in the human engineering of equipment and materiel.

In military clothing, a distinction is made between dress clothing and field clothing. Army women, of course, have their own dress uniforms, but recently considerable discussion has developed

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TABLE 1. STATISTICAL VALUES FOR U. S. ARMY WOMEN

	<u>N</u>	<u>Mean</u>	<u>S.D.</u>	<u>Range</u>		<u>Total</u>	<u>Stature Ratio</u>
				<u>Min.</u>	<u>Max.</u>		
Weight							
1946 (kg)	8107	59.63	9.00	39.0	111.6	72.6	
1977 (kg)	1331	59.97	8.69	39.9	125.1	85.2	
1946 (lbs)	8107	131.47	19.85	86.0	246.0	160.0	
1977 (lbs)	1331	132.22	19.16	88.0	275.8	187.8	
Stature							
1946 (cm)	8121	162.14	6.00	141.0	184.0	43.0	1.000
1977 (cm)	1331	162.96	6.52	142.6	183.8	41.2	1.000
1946 (in)	8121	63.84	2.36	55.5	72.4	16.9	1.000
1977 (in)	1331	64.16	2.57	56.1	72.4	16.3	1.000
Sitting Height							
1946 (cm)	8119	83.66	3.19	71.0	97.0	26.0	.516
1977 (cm)	1331	85.08	3.59	73.1	96.2	23.1	.522
1946 (in)	8119	32.94	1.26	28.0	38.2	10.2	.516
1977 (in)	1331	33.49	1.41	28.8	37.9	9.1	.521
Bust Circum.							
1946 (cm)	8115	88.91	7.68	68.0	128.0	60.0	.548
1977 (cm)	1331	88.21	6.43	68.9	128.4	59.5	.541
1946 (in)	8115	35.00	3.02	26.8	50.4	23.6	.548
1977 (in)							
Waist Circum.							
1946 (cm)	8115	67.00	6.24	52.0	110.0	58.0	.413
1977 (cm)	1331	71.01	6.90	56.5	117.5	61.0	.436
1946 (in)	8115	26.38	2.46	20.5	43.3	22.8	.410
1977 (in)	1331	27.96	2.72	22.2	46.3	24.1	.430
Hip Circum.							
1946 (cm)	8113	95.09	6.70	74.0	126.0	52.0	.586
1977 (cm)	1331	95.52	6.39	77.4	134.6	57.2	.586
1946 (in)	8113	37.44	2.64	29.1	49.6	20.5	.586
1977 (in)	1331	37.61	2.51	30.5	53.0	22.5	.586
Age							
1946 (yrs)	8118	27.30	5.57	16.0	52.0	36.0	
1977 (yrs)	1331	23.10	5.40	17.0	60.0	43.0	

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TABLE 2. PERCENTILE VALUES FOR U. S. ARMY WOMEN

	<u>1st</u>	<u>5th</u>	<u>25th</u>	Median <u>50th</u>	<u>75th</u>	<u>95th</u>	<u>99th</u>	Range (1st-99th)
Weight								
1946 (kg)	44.0	47.4	53.2	58.3	64.7	76.5	86.6	42.6
1977 (kg)	42.7	46.6	54.1	59.6	65.1	74.5	83.8	41.1
1946 (lbs)	97.0	104.4	117.2	128.6	142.7	168.6	191.0	94.0
1977 (lbs)	94.2	102.8	119.3	131.4	143.6	164.3	184.8	90.6
Stature								
1946 (cm)	148.6	152.4	158.0	162.0	166.2	172.2	176.6	28.0
1977 (cm)	148.2	152.6	158.4	162.8	167.3	174.1	178.4	30.2
1946 (in)	58.5	60.0	62.2	63.8	65.4	67.8	69.5	11.0
1977 (in)	58.3	60.1	62.4	64.1	65.9	68.5	70.2	11.9
Sitting Height								
1946 (cm)	76.2	78.4	81.5	83.7	85.8	88.9	91.1	14.9
1977 (cm)	76.3	79.0	82.7	85.2	87.6	90.8	92.1	16.4
1946 (in)	30.0	30.9	32.1	32.9	33.8	35.0	35.9	5.9
1977 (in)	30.0	31.1	32.6	33.5	34.5	35.8	36.5	6.5
Bust Circum.								
1946 (cm)	74.6	78.2	83.4	87.9	93.4	103.3	110.9	36.3
1977 (cm)	76.2	78.4	83.7	87.9	92.1	99.0	105.8	29.6
1946 (in)	29.4	30.8	32.8	34.6	36.8	40.6	43.7	14.3
1977 (in)	30.0	30.8	33.0	34.6	36.2	39.0	41.7	11.7
Waist Circum.								
1946 (cm)	56.2	58.8	62.6	66.0	70.4	79.0	86.5	30.3
1977 (cm)	59.0	61.7	66.3	70.0	74.6	83.5	92.4	33.4
1946 (in)	22.1	23.1	24.6	26.0	27.7	31.1	34.1	12.0
1977 (in)	23.2	24.3	26.1	27.6	29.4	32.9	36.4	13.2
Hip Circum.								
1946 (cm)	82.3	85.4	90.4	94.4	99.0	107.3	114.7	32.4
1977 (cm)	81.6	85.5	91.3	95.3	99.4	106.1	112.2	30.6
1946 (in)	32.4	33.6	35.6	37.2	39.0	42.2	45.2	12.8
1977 (in)	32.1	33.7	35.9	37.5	39.1	41.8	44.2	12.1
Age								
1946 (yrs)	21.1	22.7	23.7	25.9	30.2	39.7	47.2	26.1
1977 (yrs)	17.2	17.7	19.1	22.0	25.1	33.6	45.7	28.5

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over the question of whether women could or should wear men's field clothing, such as fatigues, cold weather clothing, and combat boots. In the area of equipment and materiel, such as wheeled or tracked vehicles, aircraft, control consoles, or other types of workspaces and equipment systems, human engineering considerations with respect to design and sizing usually have been based upon the body sizes of men. Thus a situation now has developed which emphasizes a requirement for the analysis and comparison of body size data for both men and women, whether for clothing or for equipment.

Anthropometric data for selected body measurements of Army men and women are given in Table 3. The data for men are from the anthropometric survey of 1966, while the women's data are from the recent 1977 survey. The statistical values shown in Table 3 are the same as those in Table I.

Average age of the two samples is similar, with the women about one year older. On the average, Army men are about 27 pounds heavier, four and one-half inches taller in stature, and two and one-quarter inches taller in sitting height. In body girth, the men are over two inches larger in chest circumference than the women are in bust circumference. In waist circumference, the men are over three and one-half inches larger than women, but in hip circumference women are one-half inch larger on the average. Differences in proportions also are indicated by these data. Although chest/bust circumference is about 54 percent of stature for both men and women, differences in proportion are more marked in waist and hip girths. Waist and hip are 46 percent and 54 percent, respectively, of stature for men, but for women they are 44 percent and 59 percent, respectively, of stature. These differences in proportion are a major problem in the consideration of whether women could wear men's field clothing. However, the possibility of developing a sizing system for clothing which would include sizes suitable for both men and women is under investigation.

The differences in body size and proportions between Army men and women also are emphasized in a comparison of the percentile values shown in Table 4. For example, while 50 percent of Army men are heavier than 156 pounds and taller than 68.7 inches, only 10 percent and 4 percent of women, respectively, are above these median values for men. Men are larger than women in chest and waist circumferences, but above the 5th percentile level, women are larger than men in hip circumference.

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TABLE 3. STATISTICAL VALUES FOR U. S. ARMY MEN AND WOMEN

		<u>N</u>	<u>Mean</u>	<u>S.D.</u>	<u>Range</u>		<u>Total</u>	<u>Stature</u> <u>ratio</u>
					<u>Min.</u>	<u>Max.</u>		
Weight								
Men	(kg)	6677	72.23	10.60	45.2	128.7	83.5	
Women	(kg)	1331	59.97	8.69	39.9	125.1	85.2	
Men	(lbs)	6677	159.10	23.35	99.5	283.5	184.0	
Women	(lbs)	1331	132.22	19.16	88.0	275.8	187.8	
Stature								
Men	(cm)	6682	174.52	6.61	151.8	199.7	47.9	1.000
Women	(cm)	1331	162.96	6.52	142.6	183.8	41.2	1.000
Men	(in)	6682	68.71	2.60	59.7	78.6	18.9	1.000
Women	(in)	1331	64.16	2.57	56.1	72.4	16.3	1.000
Sitting Height								
Men	(cm)	6682	90.69	3.66	77.2	103.2	26.0	.520
Women	(cm)	1331	85.08	3.59	73.1	96.2	23.1	.522
Men	(in)	6682	35.70	1.44	30.4	40.6	10.2	.520
Women	(in)	1331	33.49	1.41	28.8	37.9	9.1	.521
Chest/Bust								
Men	(cm)	6682	93.77	6.69	71.8	124.2	52.4	.537
Women	(cm)	1331	88.21	6.43	68.9	128.4	59.5	.541
Men	(in)	6682	36.92	2.63	28.2	48.9	20.7	.537
Women	(in)	1331	34.73	2.53	27.1	50.6	23.5	.541
Waist Circum.								
Men	(cm)	6682	80.29	8.18	58.8	127.7	68.9	.460
Women	(cm)	1331	71.01	6.90	56.5	117.5	61.0	.436
Men	(in)	6682	31.61	3.22	23.1	50.3	27.2	.460
Women	(in)	1331	27.96	2.72	22.7	46.3	24.1	.436
Hip Circum.								
Men	(cm)	6682	94.21	6.25	77.2	134.2	57.0	.540
Women	(cm)	1331	95.52	6.39	77.4	134.6	57.2	.586
Men	(in)	6682	37.09	2.46	30.4	52.8	22.4	.540
Women	(in)	1331	37.61	2.51	30.5	53.0	22.5	.586
Age								
Men	(yrs)	6682	22.17	4.64	17.0	55.0	38.0	
Women	(yrs)	1331	23.10	5.40	17.0	60.0	43.0	

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TABLE 4. PERCENTILE VALUES FOR U. S. ARMY MEN AND WOMEN

	<u>1st</u>	<u>5th</u>	<u>25th</u>	Median <u>50th</u>	<u>75th</u>	<u>95th</u>	<u>99th</u>	Range (<u>1st-99th</u>)
Weight								
Men (kg)	52.6	57.4	64.8	71.0	78.4	91.6	103.0	50.4
Women (kg)	42.7	46.6	54.1	59.6	65.1	74.5	83.8	41.1
Men (lbs)	116.0	126.3	142.6	156.3	172.6	201.9	226.9	110.9
Women (lbs)	94.2	102.8	119.3	131.4	143.6	164.3	184.8	90.6
Stature								
Men (cm)	158.9	163.8	170.1	174.4	178.9	185.6	190.3	31.4
Women (cm)	148.2	152.6	158.4	162.8	167.3	174.1	178.4	30.2
Men (in)	62.6	64.5	67.0	68.7	70.4	73.1	74.9	12.3
Women (in)	58.3	60.1	62.4	64.1	65.9	68.5	70.2	11.9
Sitting Height								
Men (cm)	82.0	84.5	88.2	90.8	93.2	96.7	99.2	17.2
Women (cm)	76.3	79.0	82.7	85.2	87.6	90.8	92.7	16.4
Men (in)	32.3	33.3	34.7	35.7	36.7	38.1	39.0	6.7
Women (in)	30.0	31.1	32.6	33.5	34.5	35.8	36.5	6.5
Chest/Bust								
Men (cm)	80.9	84.1	89.1	93.0	97.7	105.9	112.8	31.9
Women (cm)	76.2	78.4	83.7	87.9	92.1	99.0	105.8	29.6
Men (in)	31.8	33.1	35.1	36.6	38.5	41.7	44.4	12.6
Women (in)	30.0	30.8	33.0	34.6	36.2	39.0	41.7	11.7
Waist Circum.								
Men (cm)	66.3	69.7	74.5	78.9	84.7	95.9	105.6	39.3
Women (cm)	59.0	61.7	66.3	70.0	74.6	83.5	92.4	33.4
Men (in)	26.1	27.4	29.3	31.0	33.4	37.8	41.6	15.5
Women (in)	23.2	24.3	26.1	27.6	29.4	32.9	36.4	13.2
Hip Circum.								
Men (cm)	82.0	85.1	89.8	93.6	97.9	105.5	112.0	30.0
Women (cm)	81.6	85.5	91.3	95.3	99.4	106.1	112.2	30.6
Men (in)	32.3	33.5	35.4	36.8	38.6	41.6	44.1	11.8
Women (in)	32.1	33.7	35.9	37.5	39.1	41.8	44.2	12.1
Age								
Men (yrs)	17.4	18.6	19.6	20.6	23.0	31.5	43.0	25.6
Women (yrs)	17.2	17.7	19.1	22.0	25.1	33.6	45.7	28.5

With respect to clothing, women are at a disadvantage in attempting to wear men's field clothing, as, in general, it is too large in girth and too long in length, particularly in sleeve length and trouser length. In the area of vehicles or other equipment designed and sized for men, women are at a disadvantage in sitting height (or eye height), arm reach, and leg reach. These problems of compatibility are accentuated, of course, in the case of short or small women. For example, 44 percent of Army women are below the men's 5th percentile value for sitting height, 80 percent of women are below the men's 5th percentile value in functional arm reach, and 62 percent of women are below the men's 5th percentile in functional leg length. Design criteria for the human engineering of equipment and materiel for Army use obviously should include reference to anthropometric data for both men and women.

Strength of Men and Women

In addition to the collection of data on body size, the recent anthropometric survey of U. S. Army women afforded an opportunity to obtain new and unique data on the static muscle strength of Army women. Strength measurements were made on 349 women in nine different positions. Six of these were two-handed pulls, four of which were made in a standing position and two in a seated position; three other measurements were one-handed pulls. Measurements were made at fixed distances above the floor, using a strain gauge and a force meter with an optical readout which displayed a peak force and an average force during a three-second interval. Each subject performed two trials in each position. Forces were recorded in pounds.

Similar strength data also were obtained on a series of 102 U. S. Army men. Thus some comparable data on the strength capabilities of both Army men and women are now available for direct comparisons of physical performance.

In this series of strength measurements, maximum forces were exerted by men in a standing two-handed pull at a 38cm level. The mean force for this position was 229 pounds, with 5th and 95th percentile values of 166 and 303 pounds, respectively. By comparison, women showed a mean force of 128 pounds under these conditions, with 5th and 95th percentile values of 74 and 184 pounds, respectively. Thus the average strength capability of women in this measurement was about 56 percent of that of men. At waist level (100cm), men could pull an average force of 146 pounds with two hands, while the comparable value for women was 68 pounds or about 47 percent of the

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men's value. At shoulder height (150cm), men could push upwards with a force of 150 pounds on the average, but at the same level of 150cm, women could push upwards with a force of 57 pounds, or 38 percent of the men's value.

These comparisons of the strength capabilities of Army men and women emphasize the problems which will be encountered in the area of physical tasks expected to be performed by Army personnel. These data already have been utilized in a review and evaluation of lifting and carrying tasks listed for the MOS categories which are under consideration for assignment to women in the Army.

This brief discussion of the comparative strength capabilities of Army men and women also points up the critical importance of human factors considerations in the design, sizing, configuration, and portability of equipment. Equipment or components which must be lifted, carried, loaded or unloaded obviously must be suitably designed in size, weight, and configuration, and provided with the necessary hand-holds if they are to be handled effectively by individuals or by crews of several people, whether they be men or women.

As the result of a new anthropometric survey of U. S. Army women carried out in 1977, current data now are available on the body sizes, proportions, and distributions of Army women. New information also has been obtained on Army women for workspace measurements and for static muscle strength measurements. The new anthropometric data indicate that there has been relatively little change in the body dimensions of Army women. However, comparisons of data for men and women clearly show that serious design and sizing problems will be encountered in the development of clothing, equipment and materiel intended for use by both Army men and women.

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